acidity from at least some of its vacuoles, for certain of these may assume a cH widely differing from that of the rest. Parenthetically it may be remarked that *Pelomyxa* is a gross feeder and is usually crammed with algae, diatoms, small animals, sand and débris. These lie in the vacuoles and the living ingesta are for the most part apparently uninjured by their situation, proving the innocuous character of the contents of the ordinary vacuoles. An occasional vesicle, however, may assume digestive functions. Usually a few of these are to be seen in any large *Pelomyxa*. I have watched the acidity increase in an ordinary vacuole until the neutral red assumed a deep purple or bluish tint. The contained alga, green and apparently healthy to begin with, having its own vacuole stained orange by the dye, lost the orange hue of its sap, lost its green color and became ultimately disorganized. At a later stage one finds in such vacuoles only a collection of strongly stained granules in rapid Brownian movement. The granules diminish in number, apparently passing into the protoplasm, and the hue of the indicator returns to normal. Very occasionally an alkaline vesicle may be observed—deep yellow with neutral red—containing a few granules (still of the same deep red color as in an acid vacuole). Since the ordinary vacuoles do not contain granules this may represent a subsequent stage in the history of a digestive vacuole.

These phenomena illustrate very well how, even in a liquid circulating mass of protoplasm, chemical substances and chemical operations may be localized within narrow limits. More particularly they demonstrate that the H-ion concentration of a vacuole can be no criterion of that of the protoplasm that surrounds it—may indeed be such as applied externally would be lethal.

Similarly, the absence of any distinct local variations in cH in the vesicles of *Pelomyxa* during the cycle of physical changes that attends its amoeboid movement does not prove that no such variations of cH take place in the protoplasm.

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THE TOTAL IONIZATION PRODUCED IN AIR BY ELECTRONS OF VARIOUS ENERGIES

RECENT experiments on the total ionization produced by slow electrons in air have yielded results in agreement with the Bohr[1] theory of ionization in the region of the faster, low-speed electrons for which exact ionization experiments had not previously been performed. Since the experiments with very slow electrons have indicated an increase in the ionizing efficiency of electrons with increasing speed and experiments with hard cathode-rays and β-rays have shown the same quantity to decrease with increasing velocities it appeared that a maximum value must lie somewhere in the intervening range.

Previous experiments with low-speed particles have been limited in their application due to the fact that at the pressures used the electrons with the greater energies in this range hit the sides of the ionization chamber before their energy had been exhausted. In these experiments an ionization chamber of hemispherical shape was sealed off from the tube where the electrons were emitted from a hot tungsten filament, except for a small capillary hole in the anode, one end of which was 2 mm from the filament and the other end at the geometric center of the ionization chamber. By running a diffusion pump system during the experiment, and adjusting an artificial leak into the ionization chamber the air pressure in the filament tube was kept between 0.0001–0.001 mm, while the pressure in the chamber was varied at will from 0.001 to 1.5 mm. The latter pressure was adjusted until the radius of the vessel was just greater than the range of the electrons used, and the number of electrons which passed into the chamber and the number of positive ions produced by them were measured with a quadrant electrometer. This was done at frequent voltage intervals as the accelerating voltage between the filament and the anode was raised to 1,500 volts, and a graph was made of the number of ions produced per electron plotted against the energy of the electrons expressed in volts.

Bohr's theory considers both primary and secondary ionizations and predicts that, for a gas with a single ionization potential, ionization will set in when the energy of the colliding electron expressed in volts is equal to this potential. The average ionization produced per unit path will rise rapidly to a maximum at twice the ionization potential and then decrease slowly; for gases with several ionization potentials the position of the maximum is shifted to higher voltages. R. H. Fowler[2] has shown that a numerical factor of approximately three fourths should be introduced in the Bohr equation when the distribution of the velocities of emission of the secondary electrons is taken into account. The theory also predicts sudden breaks in the ionization curves when the accelerating voltage becomes equal to large ionization potentials compared to which the other potentials are small. This should occur in air at potentials belonging to electrons on inner rings of argon, nitrogen and oxygen. Assuming that all the energy of the electron

[1] Bohr, N., *Phil. Mag.*, *25*, 101 (1923); *30*, 581 (1915).

[2] Fowler, R. H., *Proc. Camb. Phil. Soc.*, 21, 521, 531 (1923).

will be used in ionizing collisions Bohr has derived an expression for the range of the electrons, which for small velocities gives a fourth-power relationship between the velocity of the electron and its range, with a deviation from this law when the ratio of its velocity to the velocity of light is not negligible.

An examination of the experimental curve obtained has shown that ionization of air by electrons sets in at about 17 volts, the ionization potential of the nitrogen molecule, and rises rapidly to a maximum between 125–130 volts, a value in agreement with Mayer's[3] determination of this maximum which is due to primary ionizations. The curve rises again when secondary ionization starts near 170 volts, and sudden breaks in the curve occur at approximately 250 volts, 375 volts and 500 volts, the ionization potentials of the L-electrons of argon and the K-electrons of nitrogen and oxygen. These potentials are in agreement with the values obtained in the X-ray and photoelectric experiments of Kurth,[4] and Mohler and Foote[5] with nitrogen and oxygen, and in the recent ionization experiment of ughes and Klein[6] with argon. In this region the efficiency of ionization is never more than 20 per cent., as also has been observed by Hughes and Klein.[6] Above 550 volts ionization increases rapidly until near 1,000 volts the rate of increase becomes steady. Determinations of total ionization have been made up to 1,500 volts.

For a number of voltages the critical pressure for which the radius of the chamber was equal to the corresponding range of the electron was measured, and a graph shows that a good linear relation exists between the energy of the electron expressed in volts and the square root of the corresponding critical pressure. The slope of the line leads to the following form of the voltage-range law for low-speed electrons, where V is given in volts, and R is measured in cm at 760 mm pressure:

$$V = 16300 \sqrt{R}$$

In other words, this is another verification of the fourth-power relationship between the velocity and range of an electron, first experimentally verified by Whiddington.[7]

In his recent cloud experiments C. T. R. Wilson[8] has measured the length of ionization tracks which are probably due to electrons of 7,700 and 8,600 volt energies, from which he has deduced a value of 21,000 for the coefficient in the voltage-range equation. For such voltages the variation of the mass of the electron with its velocity is not negligible and becomes large in the range of velocities used in the absorption experiments of Schonland[9] with cathode rays, and Varder[10] with β-rays. Their results lead to a determination of the coefficient which varies from 22,000 to 7,000 as the velocity of the particle increases. As Fowler has pointed out the value of the coefficient as predicted by the Bohr theory for low velocities, about 7,000, should be multiplied by a numerical factor of 2 or 3.

By use of the above experimentally determined law and the average value of the total ionization produced by electrons at the various energies used in the experiment, the average ionization per cm of path at 1 mm pressure was calculated and the resulting graph gave a sharp maximum near 990 volts with an expenditure of about 24.1 volts of energy per ion pair, which is approximately the value predicted by Fowler and slightly less than that determined by Wilson at higher voltages. It appears that for high voltages primary ionization of air consists of the emission of the K-electrons of the oxygen atom and that secondary ionization is due to the emission of the L-electrons from nitrogen.

It is possible to compare the values for the ionization produced by the highest speed electrons used in the experiment with the results obtained by Glasson[11] with hard cathode rays. For voltages beyond 1,000 the total ionization increases at a steady rate, so that by extrapolation and by use of the voltage-range equation a value of 1.43 ions per cm has been calculated for 4,000-volt electrons, as compared with the value, 1.5, determined by Glasson at this voltage.

It has seemed advisable to make a short preliminary report of the results of this experiment which verify the Bohr theory of ionization as corrected by Fowler, since the publication of the detailed description of the experiment may be delayed by an attempt to extend the range of voltages used in the experiment.

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